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An Innovative Approach in Developing Standard Professionals by Involving Software Engineering Students in Implementing and Improving International Standards

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Introduction

Today, the ability of organizations to compete, adapt, and survive depends increasingly on software. Some cellular phones, for example, contain over twenty million lines of code, and top of the line automobiles may have up to 100 million lines of code.[1] Manufacturers depend increasingly on the components produced by their suppliers. A manufacturing chain of large mass-market products often has a pyramidal structure, as illustrated in Figure 1, adapted from Shintani.[2] For example, a large mass product manufacturer integrated into one of its products a part with an unknown software error that was produced by one of its 6,000 lower-level producers. This defective part resulted in a loss of over $200 million by the mass product manufacturer. A vast majority of these low level suppliers are very small entities.

Industry recognizes the value of Very Small Entities (VSEs), i.e. enterprises, organizations departments or projects having up to twenty-five people, in contributing valuable products and services. A large majority of enterprises worldwide are VSEs. In Europe, for instance, as illustrated in Table 1[3], over 92% of enterprises have less than ten employees. In Brazil, IT companies with less than twenty people represent about ninety-five percent of the number of companies.[4]

Most VSEs have characteristics which make them different to larger organizations. As an example, their processes are performed informally and are rarely documented. Most VSEs do not use standards, and their perception is that standards have been developed by and for large organizations, with no attention to very small organizations. Most VSEs can neither afford the resources, in terms of number of employees, budget and time, nor do they see a net benefit in establishing software lifecycle processes. To rectify some of these difficulties, a set of standards and guides have been developed to meet the needs of VSEs.

A new set of standards and guides, ISO/IEC 29110, *Lifecycle profiles for Very Small Entities*, has been developed to meet the needs of VSEs.[5] ISO/IEC 29110 has been successfully used in undergraduate and graduate software engineering courses at l'École de technologie supérieure (ÉTS).

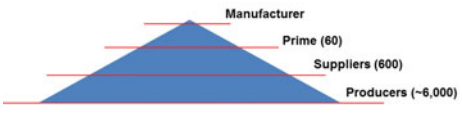

Figure 1: Example of the supply chain of a major manufacturer

Type of enterprise	Number of employees	Annual turnover (EURO)	Number of enterprises (% of overall)	Number of enterprises
Micro-enterprises	1 - 9	≤ 2 million	92.2 %	19 968 000
Small enterprises	10 - 49	≤ 10 million	6.5 %	1 358 000
Medium enterprises	50 – 249	≤ 50 million	1.1 %	228 000
SMEs, total	87 100 000		99.8 %	21 544 000*
Large enterprises	> 250	> 50 million		
Large enterprises, Total	42 900 000		0.2 %	43 000

* Independent companies only, excluding legally independent companies that are part of large enterprises.

Table 1: Size of enterprises in Europe

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ÉTS is a 7,800-student engineering school in Montréal. Three projects, conducted by graduate students (many of whom work full time in an organization and conduct their studies on a part time basis) are presented. The students have easily learned and implemented the new ISO/IEC 29110 standard in very small organizations and even in large organizations. Some students also participated to the development and translation of support material to the standard. Other students, when implementing the ISO/IEC 29110 standards and guides, provided suggestions to improve them.

A cost and benefit evaluation, using the recently published ISO Methodology to assess the economic benefits of implementing the ISO/IEC 29110 standard in a Canadian engineering firm is presented. Also, collaborations between ÉTS and Peruvian and Haitian universities to teach and use ISO/IEC 29110 in VSEs are presented. A project to adapt the ISO/IEC 29110 to the teaching of software development in technical colleges is discussed. Finally, a qualitative study of ten Irish start-up VSEs was conducted to gauge their opinion, attitude and sentiment towards of the new standard. The data from these various activities suggests that a potentially significant way to develop standards professionals (and to improve standards) is by having graduate students involved in the application and improvement of international standards in VSEs.

Overview of ISO/IEC 29110

Before presenting, in the next sections, the approach used to train and get graduate students involved in standardization, we briefly introduce the ISO/IEC 29110 standard used in our approach.

ISO/IEC 29110 has been originally defined as applicable to a vast majority of VSEs that do not develop critical systems or critical software. ISO/IEC 29110 provides to VSEs a four-step road map, also called a 'Profile'; the four profiles are Entry, Basic, Intermediate and Advanced. VSEs targeted by the Entry profile are VSEs working on small software projects (e.g. at most, six person-months effort) and for start-up VSEs. The Basic profile describes software development practices of a single application by a single project team of a VSE. The Intermediate profile is targeted at VSEs developing more than one project with more than one team. The Advanced profile is target to VSEs that want to sustain and grow as an independent competitive software development business.

At the request of ISO/IEC JTC1 Subcommittee (SC) 7 Working Group (WG) 24, mandated to develop ISO/IEC 29110, all technical reports are available at no cost from ISO.[6] The Management and Engineering Guide, the most valuable document for VSEs, has being translated in French by Canada and in Spanish by Peru and adopted as a Peruvian national standard. The set of five documents has been translated in Portuguese by Brazil, Spanish by Uruguay, and by Japan as national standards. The Management and Engineering guide of the Entry profile[7] has been published in 2012 in English, in French and in Spanish. The reader who would like to read more about this standard is invited to consult the articles publicly available on the public web site of the ISO/IEC 29110 standard.[8]

Role	Task List	Input Products	Output Products
PM CUS	PM.1.2 Define with the Customer the *Delivery Instructions* of each one of the *Deliverables* specified in the *Statement of Work.*	*Statement of Work [reviewed]*	*Project Plan* • → *Delivery Instructions*

Table 2: Example of one task of the Project Planning Activity

Figure 2[9] illustrates the two processes of the Basic profile, described in the Management and Engineering guide,[10] for VSEs developing software: the Project Management (PM) process and the Software Implementation (SI) process.

The ISO working group mandated to develop ISO/IEC 29110 decided to include a project management process since it is a weakness of many VSEs and their financial success depends on successful project completion within schedule and on budget, as well as on making a profit. The other process of ISO/IEC 29110 is the process, titled software implementation process, is dedicated to the development of a software product and its documentation.

For illustration purposes, one task of the ISO/IEC 29110 Project Planning activity is listed in Table 2 from ISO/IEC TR 29110-5-1-2:2011. On the left side of the table are listed the roles involved in a task. The Project Manager (PM) and the Customer (CUS) are involved in these 2 tasks. On the right side on the table, we listed the product required as an input to perform a task as well as the products produced by a task. In the next sections, we will describe how this new standard was used by graduate students to implement software engineering practices in real organizations and how they contributed to the improvement of ISO/IEC 29110 standards and guides.

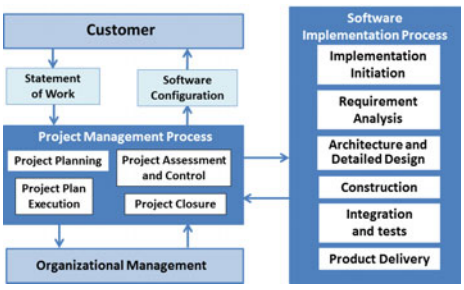

Figure 2: Project Management and Software Engineering Processes of ISO/IEC 29110

Software Process Improvement Course

The graduate Software Process Improvement (SPI) course of ÉTS is taught in the lecture format within the Software Engineering curriculum. The objective of the graduate software engineering program is to train professionals already active in the development or maintenance of software. Students of the SPI course have to perform an intervention in an organization where they would identify an improvement opportunity and implement it in a team of three students. The objectives of the SPI course are:

- Identify weaknesses in the organizational software processes;
- Prepare a business case about the cost and benefits of the intervention;

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- Prepare a communication plan and a process improvement plan;
- Define or modify a software process;
- Identify and manage risks associated with the process improvement project;
- Identify the human and organizational factors which may harm or help improve the process;
- Document the improvements to the process;
- Conduct a pilot project to test the proposed improvements;
- Document a project retrospective (i.e. document the lessons learned).

Since ISO/IEC 29110 was made publicly available by ISO at no cost, this standard was identified as a framework for the student projects. Working graduate students were able to rapidly understand it and use it in organizations.

Since students are not just doing a static analysis of the standard but had to implement a subset of the standard in real organizational processes, they are much more critical about the understandability, completeness, and usability of the standard. In addition, since some of the documents of the set of ISO/IEC 29110 standards and guides were, a few years ago, under development, students were presented with the ISO development process and were invited to make comments about the documents being developed such as areas of potential misinterpretation and identification of weaknesses in the draft ISO/IEC 29110 documents. The comments provided by students were analyzed and incorporated in the set of formal comments submitted by Canada to ISO.

A few students also decided to complete the requirements of the graduate software engineering program by doing their project in an organization using the set of ISO/IEC 29110 standards and guides.

Implementation of ISO/IEC 29110 in a Software Start-up Enterprise

A software development project has been conducted by a two-person start-up enterprise.[11] The objective of the project was to develop a social networking web site for travelers. The new ISO/IEC 29110 standard developed specifically for start-ups and very small entities was used to develop the software of a web application. This web application allows users to collaborate, share and plan their trips in a simple way and accessible to all members of a network of friends. This project took 990.5 hours to manage and to develop the software.

As illustrated in Table 3, the effort devoted to prevention such as the installation of the environment (e.g. server, tools) took 89 hours; the execution of the tasks was 716 hours. This effort does not include effort to review artefacts and to correct the defects. The effort to review artefacts has been 60.5 hours and 125 hours were devoted to the correction of defects (i.e. rework). Using the proven software engineering practices of the ISO/IEC 29110 standard, to plan the project and execute the project allowed the two-person team to spend only thirteen percent of the total project effort on rework (i.e. wasted effort). The team spent about nine percent of the total project effort in prevention tasks and six percent in evaluation tasks such as desk-check peer reviews and tests.

This project has demonstrated that, by using ISO/IEC 29110, it was possible to

Title of Task	Prevention (Hours)	Execution (Hours)	Review (Hours)	Correction of defects (Hours)
Environment installation (server, work stations, tools)	**89**			
Project plan development		**35**	**3**	**4**
Project plan execution and project assessment and control		**47**		
Project plan execution		21		
Project assessment and control		26		
Specification development and prototype development		**199,5**	**7**	**18**
Statement of Work		34	2	13
Requirements specification		54	2	,5
Prototype development		93	3	17
Architecture development		**42,5**	**1,5**	**3,5**
Test plan development		**12,5**	**1**	**2**
Code development and code testing		**361**	**47**	**96,5**
Home page		94		
Research		27,5		
Portfolio		28		
Trip		78,5		
City		41		
Activity		56,5		
Profile		29,5		
Administration tools		6		
User guide and maintenance document development		**8**	**1**	**1**
Web site Deployment		**8,5**		
Project closure		**2**		
Total (Hours)	**89**	**716**	**60,5**	**125**

Table 3: Effort to prevent, execute, detect, and correct errors by the two-member team

properly plan and execute the project and develop the software product using proven software practices as well as not interfering with the creativity during the development of the web site. People who think that standards are a burden, an unnecessary overhead and a threat to creativity, should look at this start-up project and revisit their assumptions.

Implementation of ISO/IEC 29110 in an Engineering Start-up Enterprise

An implementation project has been conducted in a start-up VSE specialized in the integration of interactive, communication systems, visual information and media, and vehicle wayside communications in the public transportation field such as trains and buses.[12] In this domain, customers often require a CMMI® maturity level[13] such as a CMMI Level 2 for sub-system suppliers.

In 2012, the VSE was composed of just four professionals. It was felt that implementing the Level 2 process areas of the CMMI was too demanding at that time. The start-up decided to implement the draft version of ISO/IEC 29110 systems engineering Basic profile, illustrated in Figure 3[14], as a foundation for its development work. It was felt that, once the processes would have been documented and implemented in a few projects, the VSE could, if required, perform a gap analysis between the CMMI® Level 2 practices and the Basic profile and implement the practices needed for a Level 2 assessment.

The reader may notice that Figure 3 is quite similar to Figure 2. The reason is that the systems engineering ISO/IEC 29110[15] was developed using the ISO/IEC 29110 for software engineering. The project management processes of the system and software engineering guides are very similar. The main differences are found in the software and system engineering activities and tasks. This explains why it was quite easy for the graduate student, who had studied and implemented the software engineering standard for VSEs, to implement the ISO1IEC 29110 systems engineering standard in a system engineering start-up enterprise. The project of the student, in close collaboration with the start-up, has been the implementation of the project management process and the implementation of the system requirements engineering tasks.

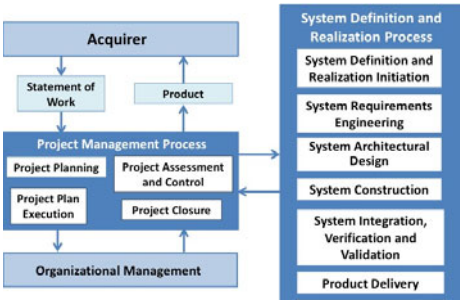

Figure 3: Processes of the Systems Engineering Basic Profile

Implementation of ISO/IEC 29110 in an Engineering Enterprise

A Canadian division of a large American engineering company had conducted a project to define and implement project management processes for their small-scale and medium-scale projects.[16] The firm already had a robust and proven process to manage their large-scale projects. Their projects are classified into three categories as illustrated in Table 4.

One division of the engineering firm used the project management process of the Entry profile of ISO/IEC 29110[17] to document their small-scale project management process and they used the project management process of the Basic profile[18] to document their medium-scale project management process.

ISO has developed "The ISO Methodology to assess and communicate the economic benefits of standards."[19] This methodology was used, by the engineering firm, to estimate the anticipated costs and benefits over a period of three years. Figure 4 from the ISO publication illustrates the value chain of the company.

An estimate of anticipated costs and benefits over a period of three years was made by the improvement program project sponsors. Table 5[20] shows the results of this cost/benefit estimation.

The engineering firm is planning to document and implement their systems engineering processes for the small-scale and medium scale projects using the recently published ISO/IEC TR 29110-5-6-2 systems engineering management standard and guide.[21]

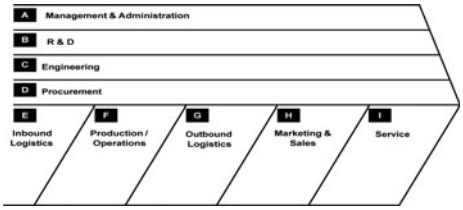

Figure 4: Value chain of the company

	Small project	Medium project	Large project
Duration of project	Less than 2 months	Between 2 and 8 months	More than 8 months
Size of team	Up to 4 people	Between 4 and 8 people	More than 8 people
Number of engineering specialties involved	One	More than one	Many
Engineering fees	Between $5,000 and $70,000	Between $50,000 and $350,000	Over $350,000
Percentage of projects	70%	25%	5%

Table 4: Classification of projects by the engineering firm

	Year 1	Year 2	Year 3	Total
Cost to implement and maintain	59 600$	50 100$	50 100$	159 800$
Net Benefits	255 500$	265 000$	265 000$	785 500$

Table 5: Costs and benefits estimations from implementing ISO/IEC 29110

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Development of ISO/IEC 29110 Educational Material for an IT Technical College

Another working graduate student of ÉTS developed, for a professor and students of an IT technical college of Montréal, a set of ISO/IEC 29110 teaching material. The graduate student, who happened to have done his college level studies in this technical college, worked with the professor responsible for the software engineering course to develop a set of templates and guides. Figure 5 (translated from Trudeau[22]) illustrates the process used to develop and validate the teaching material.

The teaching material has been tested in two software engineering courses. To evaluate if the templates met the needs and expectations of the professor and the students, two surveys have been conducted to allow them to offer their feedback. The survey illustrated that the students are interested in using the ISO/IEC 29110 standard because it helped them complete their projects more efficiently and enabled a better use of the topics presented in their courses.

The results of the project performed by a graduate student have been presented, at a workshop, to the IT professors of the technical colleges of the province of Québec.[23] This was an excellent opportunity to present the teaching material. The material will be freely available to all professors of the 48 technical colleges in Québec.

Development and Deployment of Material in Spanish by a Peruvian University

In order to facilitate the implementation of ISO/IEC 29110 a set of deployment packages (DPs) were developed by the delegates of the ISO working group mandated to develop the standards and guides. A DP is a set of artifacts developed to facilitate the implementation of a set of practices, of the selected framework, in a VSE. Hence, by deploying and implementing the package, a VSE can see what concrete step it needs to take to achieve or demonstrate compliance with a standard or model. DPs were designed such that a VSE can implement its content, without having to implement the complete framework at the same time. The table of contents of a DP is illustrated in Figure 6 (from ISO/IEC TR 29110-5-1-2:2011). Graduate software engineering students of ÉTS developed, for the ISO/IEC 29110 Entry Profile,[24] two DPs: a project management DP and a software implementation DP. The DPs are freely available on the Internet.[25]

Students of a professor at the Universidad Peruana de Ciencias Aplicadas of Lima in Peru, used the ISO/IEC 29110 standards and translated into Spanish the set of Deployment Packages developed to support the Basic profile. Figure 7 illustrates that set.[26]

This set of DPs has been used in a Peruvian VSE. Recently, that VSE was granted an ISO/IEC 29110 certificate of conformity. Graduate students also developed, as part of the Architecture DP, a procedure to support the analysis, design, and documentation of the architecture in VSEs. The requirements DP was also updated, by the Peruvian students, to better define the non- functional requirements (i.e. the quality attributes) of a software product. Peruvian graduate students were also involved in the modification of a commercial ISO/IEC 29110 tool to facilitate the utilization of the Basic Profile using an Agile approach.

1. Technical Description
   Purpose of this document
   Why this Topic is important
2. Definitions (Generic and Specific Definitions)
3. Relationships with ISO/IEC 29110
4. Detailed Description of Processes, Activities, Tasks, Steps, Roles and Products
   Role Description
   Product Description
   Artefact Description
5. Templates
6. Examples
7. Checklists
8. Tools
9. Reference to Other Standards and Models (ISO/IEC 12207, ISO 9001, CMMI)
10. References
11. Deployment Package Evaluation Form

Figure 6: Table of Content of a Deployment Package (ISO 2011)

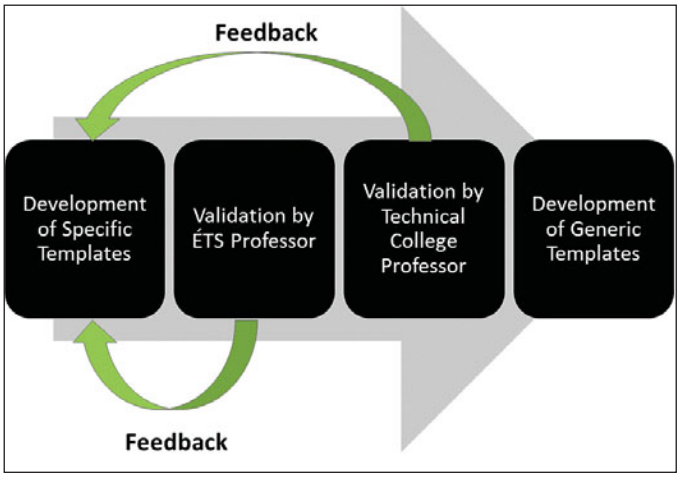

Figure 5: Teaching Material Development Process

Teaching and Implementing ISO/IEC 29110 in Haiti

A graduate of the software engineering program of Université du Québec Montréal

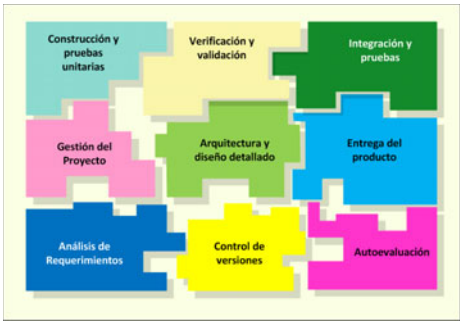

Figure 7: Set of Deployment Packages translated by students of Peru (http://profs.etsmtl.ca/claporte/English/VSE/VSE-Spanish)

has done his graduate project on the implementation of the Basic profile of ISO/IEC 29110 in two VSEs in Haiti. After completing his master's degree, he returned to Haiti as a software engineering professor at the Institut Universitaire Quisqueya-Amérique (INUQUA).[27] Since then, a few seminars have been held between ÉTS and INUQUA to present and discuss the set of ISO/IEC 29110 standards and technical reports to students of a software quality assurance course.

Over fourteen software VSEs of Haiti have been evaluated against ISO/IEC 29110 as part of a software quality assurance course taught by INUQUA. Fourteen teams of students made these evaluations. For the summer session of 2014, at least eighty students will evaluate the development processes of other VSEs using the ISO/IEC 29110 standard. At the center of research and development in information technology of INUQUA, three applications, using the minimum activities of the standard, have been developed using ISO/IEC 29110.

Application of ISO/IEC 29110 in an Undergraduate Software Quality Assurance Course

We have designed and implemented a software quality assurance course where undergraduate students apply ISO/IEC 29110 in a team project.[28]

The course includes a ten-week project in which teams of four students apply the software quality assurance practices and ISO/IEC 29110 taught in class in a software development project. In addition to software requirements analysis, architecture and detailed design, construction, integration, and tests, the teams must perform project management activities such as project planning, project plan execution, project assessment and control, and project closure as defined in ISO/IEC 29110. Teams have to measure the effort spent on the initial development of their artifacts, such the software requirements, as well as the effort spent on evaluating an artifact and correcting defects in all phases of the project. Student teams have to develop a traceability matrix showing the links between the needs stated in the statement of work, the requirements, the architecture, the tests, and the code. All versions of the artifacts have to be kept in a version control tool. The project is completed by an analysis of the measures collected and an analysis of the project to capture the lessons learned. Textbooks for this course have been developed in French[29] and in English.[30] The textbooks contain a good coverage of the activities and tasks of ISO/IEC 29110.

Evaluating Sentiment towards ISO/IEC 29110 in Ireland

Ultimately the goal of educating the next generation of standards professionals to embrace standards initiatives such as ISO/IEC 29110 in an industry setting will be strongly influenced by the attitudes, opinions, and sentiment that exist in VSEs. A series of ISO/IEC 29110 public industry briefing seminars were conducted in Dublin, Ireland among local software product VSEs, none of whom were currently utilizing ISO standards. Following from this, a detailed qualitative study[31] was conducted in ten software product VSEs, all of which were in start-up phase or recently formed (less than twenty-four months). Participating in this were individuals holding job titles such as founder, Chief Technical Officer (CTO), project manager, or owner or co-owner of the VSE. All of the subjects were educated to graduate level and were aged between twenty-seven and thirty-two years old. A semi-structured interview approach consisting of both open-ended and specific questions was used in this study in order to discuss the topics in depth and to get respondents' candid discussion on the topics.

In terms of *acceptance of standards* among VSEs, none of the VSEs currently had plans to adopt any particular standard in their software development process. Furthermore, all of the respondents reported that they had never been exposed to ISO standards as part of their formal university education and accordingly felt ill-equipped to navigate the domain of international standards and relied mostly on hearsay and/or second hand information regarding standards and the potential applicability in their companies.

The interview data analysis identified several interesting phenomena such as *Low Acceptance* and *Low Priority*. Low acceptance issues were predominately due to the perception that process standards are overly complicated, lacking in detailed implementation guidance and would require additional [unavailable] resources. Participants of the interview also believed that the processes, as generally described in software standards, are not easy to actually tailor and implement in their VSEs. In addition, the analysis also indicates that the lack of requirement from the market in general and their customer in particular has contributed to low acceptance of such standards. The interview analysis indicated that a software lifecycle standard is a low priority issue for multiple reasons including: low to no demand for standards compliance from clients; the view of standards as a 'sales tool' only; and the perception that the software lifecycle standards are designed for the big companies rather than for VSEs.

Two related major categories are the level of interest in standards and awareness of standards. These explain VSEs level of interest and awareness regarding software lifecycle standards and ISO/IEC 29110 in particular. Even though VSEs have shown low acceptance and priority level regarding standards, our analysis has also shown that there is an indicator that VSEs are interested and are aware about software process and quality standards and the potential benefits from having a quality standard, and in particular accreditation to ISO standards. Leading to a quality product, creating consistency, improving company image, creating consistency in development work, improving work process, and 'good for business' are the main points that the interviewees gave about the potential benefits of standards compliance.

The data suggests that a potentially significant way to develop standards professionals is by having experienced graduate students involved in the application

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and improvement of international standards in VSEs. Further we suggest that such initiatives, as described in this paper, may address the negative sentiment expressed above.

Conclusion

We have presented how working graduate students are involved in the implementation of the set of ISO/IEC 29110 standards and guides developed specifically for very small entities. The projects that have conducted allowed them to implement project management and engineering practices in real organizations. The graduate students were in a better position to criticize, from a practical point of view, the standards and guides. They learned the ISO standard development process and they provided feedback and comments in order to improve the ISO/IEC 29110 set of documents.

These projects have demonstrated that by using ISO/IEC 29110, it was possible to properly plan and execute projects and develop products or conduct projects using proven system or software engineering practices without interfering with the creativity of developers. People who think that standards are a burden, an unnecessary overhead, and a threat to creativity should look at these start-up projects and the application in a large engineering enterprise and revisit their assumptions.

Authors

Dr. Claude Y. Laporte has been a professor at the École de technologie supérieure (ÉTS) since 2000, where he teaches software engineering. His research interests include software process improvement in small and very small enterprises, as well as software quality assurance. He is the Editor of ISO/IEC JTC1 SC7 Working Group 24, tasked to develop ISO/IEC 29110 life cycle standards and guides for Very Small Entities. He is the Co-chair of the INCOSE Systems Engineering for Very Small Entities Working Group. He is the co-author of two French books on software quality assurance published in 2009 by Hermes Science-Lavoisier and one English textbook, on the same topic, to be published by John Wiley and Sons in 2014. His web site address is http://profs.etsmtl.ca/claporte/English/index.html

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Mr. Bruel GERANCON has been a professor of software engineering and project management in the department of computer science of the Institut Universitaire Quisquéya Amérique (INUQUA) since 2011. For the last two years he has been teaching the ISO/IEC 29110 standard in a software quality assurance course at INUQUA and implementing it in the very small enterprises (VSEs) of Haiti.

His research interests are focused on object-oriented approach, agile method, modeling of object- oriented systems, improvement of software development process in small organizations in Haiti, and software quality assurance. Presently, he serves as the deputy coordinator of the Department of Computer Science, and Executive Director of the Centre for Research in Information Technology and Communication at INUQUA. His website address is www.inuka.edu.ht

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